Lucent Digital Radio

SUBMISSION TO THE NATIONAL RADIO SYSTEMS COMMITTEE

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Mr. Milford K. Smith Jr.
Chairman, NRSC DAB Sub-Committee
PO Box 1059
Two Kennedy Boulevard
East Brunswick, NJ 08816

Dear Smitty:

Lucent Digital Radio (LDR) is pleased to submit to the NRSC a test result document which captures some of the laboratory testing LDR has performed to date. LDR continues to perform and gather both laboratory and field data as part of an ongoing process.

LDR's test plan is designed to compare the performance of a digital broadcast system with existing analog systems and to test the compatibility of a digital broadcast with the embedded base of analog receivers. In order to ensure commercial acceptance, LDR places considerable emphasis on characterizing suitable benchmarks against which such evaluations can be performed. The LDR test methodology includes four major components, which are explained in more detail in Appendix A:

Proper sampling and characterization of the analog receiver population
Audio sample selection and processing prior to transmission
Subjective audio tests
Careful selection of channel conditions for laboratory testing

The design and testing of digital systems is an iterative process. Testing results will drive design changes and modification. Thus, the results presented in these appendices are not indicative of a final design. Test results gathered after this submission will be made available upon request.

Laboratory test results are primarily used for evaluation. It is generally accepted that laboratory results are more reliable since a broader range of test can be conducted in a controlled environment. Field test should be used to as final checkpoint after extensive laboratory measurements are made. In addition, consistent with the NRSC's recent decision to perform comparative testing, it is most critical that both lab and field-tests be performed on a common and controlled test bed.

Laboratory measurements were obtained at LDR's facilities in Warren, NJ. These facilities were audited by the Department of Commerce's Institute for Telecommunications Sciences (ITS), based in Boulder, Colorado.

LDR carefully tested the latest generation of reference receivers recommended by the NRSC. These receivers were used to process analog audio for compatibility testing. In addition, LDR utilized data supplied by CEA to characterize a broader receiver population. This was done to ensure that the embedded base of receivers is properly represented and characterized.

Subjective testing was performed by Lucent's Multimedia Perception Assessment Center in Holmdel, New Jersey and Red Hill, Illinois as well as Moulton Laboratory in Groton, Mass. Audio selections chosen by LDR were used for testing. These audio selections and the corresponding rational for choosing are given in Appendix B.

FM IBOC Laboratory results are presented in Section F. These include IBOC performance in the presence of noise, 1st adjacent interference and multi-path conditions as defined by the EIA test models. The subjective assessment of audio samples as a function of distance from the transmitter is also provided.

The Compatibility of FM-IBOC is also presented. Section G provides FM-IBOC hybrid performance with the host analog signal and addresses the question of whether the digital signal impacts an analog receiver tuned to an IBOC station. Section H presents hybrid IBOC compatibility with the first adjacent analog signal and addresses the question of whether IBOC will interfere with a receiver tuned to an adjacent analog channel. Consistent with our testing philosophy, subjective testing was primarily used to perform these assessments. The conditions tested include EIA multipath conditions and various levels of signal strength.

The AM IBOC system test results are presented in Appendix J. These results are based upon objective measures (e.g: BER) and include coverage, performance with noise and performance with various interference conditions. LDR will complement this data with subjective test for AM when they become available.

A system description of the LDR hybrid and all digital systems are provided in Appendix D for FM and Appendix I for AM.

Best regards,

(Ben Benjamin)

Enclosures;

Table Of Contents

I. INTRODUCTION

Lucent Digital Radio, Inc. ("Lucent" or "LDR"), a subsidiary of Lucent Technologies Inc., is applying the expertise of Lucent's Bell Laboratories to develop a digital radio broadcast system that will make more efficient use of existing broadcast spectrum and enable the delivery of new and better services to the American public.

The Lucent IBOC systems for AM and FM each consist of two related design, one for introducing digital broadcasting by sharing existing spectrum with the existing analog signals and one for permanent all-digital broadcasting.

Lucent's hybrid system allows each AM and FM broadcaster to initiate digital broadcasting without impairing its analog signal. The more feature-rich all-digital system will enable even higher audio quality and more varied digital data services when analog signals are no longer needed. As set out in detail below and in the extensive appendices attached hereto, Lucent's system uses its patented Multi-streaming PAC™ technology to achieve clear reception even in crowded signal conditions during the transition to digital, and superior digital audio quality and data services in the all-digital environment without any need for additional spectrum being allocated to broadcasting.

II. LUCENT'S APPROACH TO TERRESTRIAL DAB

Lucent is designing IBOC AM and FM technology to provide new and improved services to the public, incorporating features in its system that appeal to both consumers and broadcasters. In this manner we seek rapid adoption of the digital technology, and more efficient use of the broadcast spectrum. The public will benefit from the increased diversity of services so enabled, and broadcasters will be better positioned to compete in the digital age.

Lucent's consumer research shows that for a given cost, market penetration of receivers will be driven by three factors of nearly equal importance:

- improved audio quality;
- enhanced information capabilities; and
- increased program choice (through either content variety/selection or improved reception).

Consumers increasingly are becoming accustomed to the high quality digital audio that is proliferating in consumer products today. Soon satellite digital audio service providers will deliver new content streams to consumers both in their homes and in their cars with high quality digital audio. Consumer research clearly indicates that radio listeners increasingly will desire comparable audio from radio stations, and that even with their strong local content, broadcasters will be under pressure to meet these audio quality expectations. Consequently, interest among AM and FM broadcasters is growing for digital technology that will enable them to compete effectively against emerging alternatives such as mobile satellite digital audio radio services ("DARS") and web radio.

Lucent is applying leading edge technology – some of it created and patented specifically for its IBOC system – to create a flexible and robust digital broadcast system capable of meeting broadcaster and consumer needs today and well into the future. Our emphasis on maximizing spectrum utilization allows us to create maximum digital capacity in the existing bands, and the flexible system design enables broadcast licensees to efficiently allocate this capacity to audio or data services, driven by market needs. Our systems are optimized to provide the highest possible audio quality and the greatest data capabilities, while maximizing robustness to channel and propagation impairments such as interference and multi-path under the full range of channel conditions. By painstakingly analyzing these impairments and applying the latest digital techniques, to the extent feasible it is our intent to design and build systems that are capable of realistically covering the entire service area of each existing radio station.

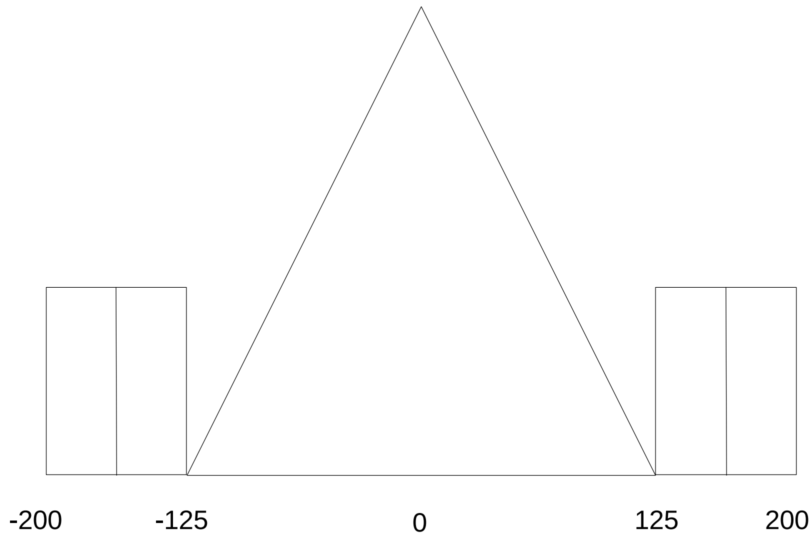
While using the existing AM and FM bands to introduce DAB to the United States is a very challenging technical task, we believe that IBOC technology is capable of delivering new and improved services to the American public, and offers the most economically efficient route to DAB. The advantages of leveraging existing transmission infrastructure, receiver economies of scale to produce low-cost digital devices, and utilizing existing AM and FM spectrum bands that have attractive propagation characteristics, favor IBOC as the preferred approach to introducing DAB. Lucent's IBOC AM and FM systems are designed to work within the existing radio environment, with a set of rich features that allow for maximum possible implementation flexibility and a platform for continued innovation of capabilities and services.

III. OVERVIEW OF LUCENT FM IBOC SYSTEM

Lucent’s FM IBOC system has two modes of operation: (1) FM hybrid mode in which low power digitally modulated signals are introduced on sidebands adjacent to the FM analog channel, and (2) FM all-digital mode in which a high power digitally-modulated signal replaces the analog signal at the end of a long transition period, with the sidebands continuing to operate as in the hybrid mode. Both these digital modes of operation are compatible with the analog mode, thereby allowing for maximum flexibility in transitioning from analog to digital. One can envision analog, hybrid, and all-digital stations operating simultaneously in the same market, thus providing the flexibility to time the transition of each of their stations based on the market and their plans.

FM HYBRID MODE

Shown below is the spectral density of the FM hybrid signal. Appendix D describes this in further detail.



FM IBOC Hybrid Signal

The digital signals, located on the edges of the analog signal, occupy two bands of about 75 kHz each. The transmitted power of the digital signal in the hybrid mode is 22 dB below the analog carrier. The digital sidebands employ Orthogonal Frequency Division Multiplexing (“OFDM”) as its modulation technology. OFDM provides inherent immunity against physical propagation problems, such as multipath, by the simultaneous transmission of many subcarriers. With our design, the net throughput achieved (after error correction) of the digitally modulated sidebands is 136 kbps. These digitally modulated signals can carry a combination of audio and data, and the capacity may be allocated flexibly. However, if CD quality audio transmission is desired, the entire

128 kbps bandwidth will need to be dedicated to audio, employing our proprietary multi-streaming PAC™ [1] encoder to deliver high quality audio even under highly impaired channel conditions.

Multi-streaming PAC™ provides for high levels of robustness resulting in (a) improved immunity to interference, (b) graceful degradation of the digital audio signal under fading conditions, and (c) efficient channel usage to deliver higher capacity. As a result, the digital signal delivers CD quality sound in clean channel conditions, with substantially higher quality than FM analog at increasing distances beyond the protected contour. This implies that the digital signal could operate independent of the analog signal providing coverage equivalent to that of the analog signal.

The hybrid system is designed to minimize interference to the host analog signal, as well as to adjacent analog signals. While there is some impact to the adjacent analog signal, it occurs at the edge of coverage of the adjacent analog signal where the signal quality expectation already is low. This impact is limited to some mobile receivers.

In order to lower implementation barriers, the system design targets a cost of $75,000 to $150,000 for a one-time (including FM all-digital) station upgrade, while keeping the cost of receivers within reach of the mass market.

FM ALL-DIGITAL MODE

In the all-digital mode the analog center channel is replaced by a high power 200 kHz OFDM signal (10 dB below the original FM analog power level),

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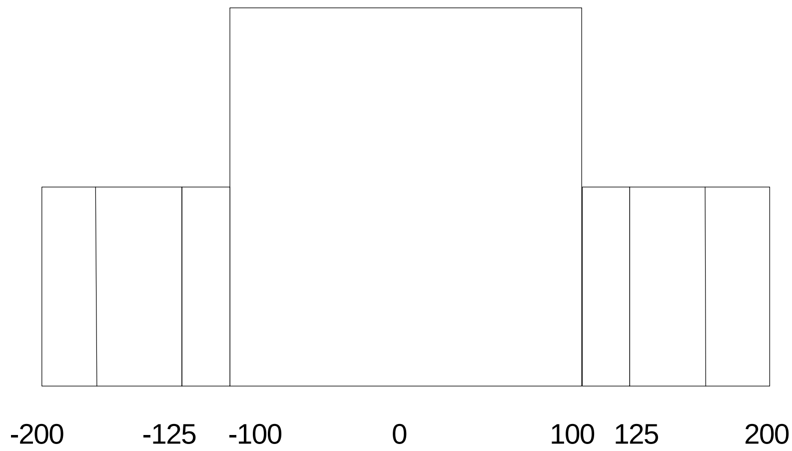
1 *See Appendix E*

while the sidebands continue to operate as in the hybrid mode. In addition, two sidebands (each 25 kHz wide) are introduced adjacent to the main center channel for additional data capacity.



FM IBOC All-Digital Signal

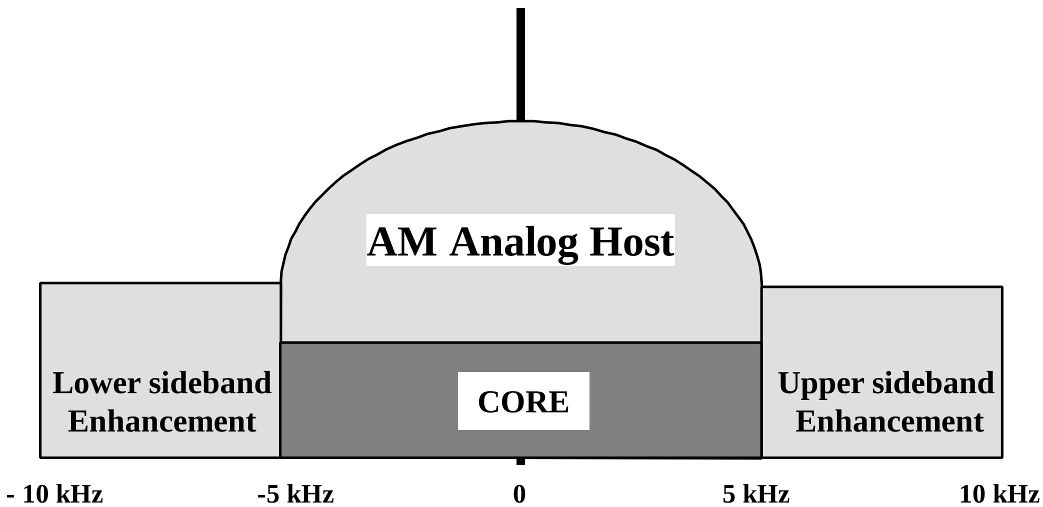
The net throughput (after error correction) of the FM all-digital center channel is 300 kbps, which again can be allocated flexibly for audio or data applications. The higher power levels and robustness allow for high capacity audio and data services, including multi-channel (5.1) surround sound (which requires 300 kbps). The digital side-bands continue to function as in the hybrid case, allowing for backward compatibility with the hybrid mode. This design allows for maximizing the spectrum utilization to offer vast increases in throughput, thereby creating maximum flexibility for licensees to offer a variety of programming choices, or alternatively to dedicate this capacity to innovative data services.

IV. OVERVIEW OF LUCENT AM IBOC SYSTEM

Similar to the FM IBOC system, our AM IBOC system also is designed for two modes of operation: (1) AM hybrid mode in which low power digitally modulated signals are introduced across 20 kHz in the AM channel, and (2) AM all-digital mode in which a high power digitally-modulated signal replaces the analog signal at the end of a transition period, with the low power digital signals continuing to operate as in the hybrid mode. Both of these digital modes of operation are compatible with the analog mode, thereby allowing for maximum flexibility in transitioning from analog to digital. One can envision analog, hybrid and all-digital stations operating simultaneously in the same market, thus providing individual stations the flexibility to time their transition based on their individual market plans.

AM HYBRID MODE

Shown below is the spectral density of the AM hybrid signal. Appendix J describes this system in further detail.



AM IBOC Hybrid Signal

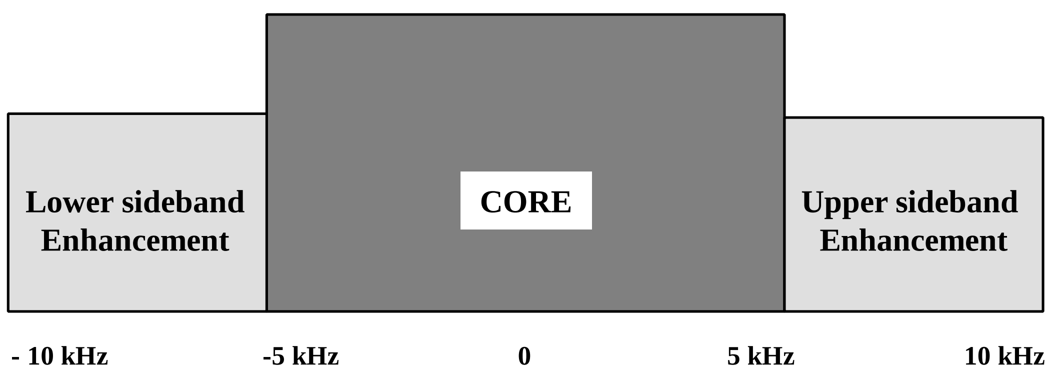
As in the FM IBOC system, the AM IBOC system uses OFDM. However, digital signals are inserted both in the sidebands and under the main AM signal. The two sidebands and the center channel constitute independent streams. This design ensures that interference from one side will not eliminate the digital signal. Unlike the FM system, the AM system does not have sufficient bandwidth to provide diversity. In this case, we achieve robustness by blending to analog. This in turn requires the content on the digital portion of the signal to be identical to that of the analog.

In the AM IBOC case, our design again uses multi-streaming PAC™ designed to operate at 48 kbps, the net throughput of the digital signal. This signal carries three streams: a core element with the main audio content, and two enhancement streams, one on each side, which improve and enhance the audio quality. Multi-streaming PAC™ in the AM system is the only technique available to counter the effects of interference from 1st and 2nd adjacent channels in the AM band.

Given the limited bandwidth of AM channels, our AM hybrid system represents an optimal solution that provides a good compromise between audio quality, coverage and compatibility with the analog host.

AM ALL-DIGITAL MODE

Shown below is the spectral density of the AM all-digital signal. Appendix J describes this system in further detail.



AM IBOC All-digital Signal

In the AM all-digital mode, the system offers net throughput of 64 kbps, sufficient for high quality audio and at least as good as current day FM. The core is transmitted at power equal to that of the analog host in the hybrid mode. This doubles the capacity over that of the hybrid mode. As in the hybrid mode, multi-streaming PAC™, operating at 64 kbps with three streams provides for equivalent coverage as analog, and good immunity to interference. In this mode, an AM station would nearly gain audio parity with FM stations, allowing for interesting possibilities for format choices and programming content.

For AM stations, the comparable costs to upgrade will vary between $20,000 and $30,000 total for stations with a stereo transmitter of compatible linearity. Reasonable costs in this range should foster a rapid roll-out of digital AM service.